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THE FUNDAMENTALS OF CROP IMPROVEMENT.[1]

By WALTER T. SWINGLE, *Physiologist in Charge of Crop Physiology and Breeding Investigations.*

INTRODUCTION.

Agriculture is rapidly changing from one of the simplest of the arts to one of the most complex and difficult, and it is making larger and larger demands for intelligent and capable activity on the part of those engaged in it. It is my purpose to outline briefly some of the essential principles underlying the more efficient agriculture that is bound to come in the future.

The fundamentals of agriculture are generally misunderstood because of the hampering European traditions which still impede our progress. It must be remembered that the agriculture of Europe is the result of several thousand years of gradual improvement of agricultural practices and an equally long period of conscious or unconscious selection of crop plants carried on by the most intelligent peasantry in the world. When we attempt, however, to transfer this European agriculture to a new continent, with climatic and soil conditions profoundly different from those of Europe, we are often hindered rather than helped by the agricultural traditions which were so deeply ingrained in our forefathers.

Briefly, then, we must face the problem of agriculture in the New World from a scientific point of view and on its own merits, utilizing to the full, of course, any crops and practices of European origin which can be adapted to our conditions. But it is becoming increasingly obvious in a great many cases that the problem must be worked out anew; and if we have to work out the problem of agriculture in the twentieth century in the New World, we must do it on a basis of scientific investigation.

Let us consider, therefore, what the scientific principles underlying crop production are. In a word, they are to secure crop plants adapted to the local climatic and soil conditions and to educate communities of farmers to produce those crops in the most efficient way.

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THE SCIENCE OF CROP PHYSIOLOGY.

The problem of securing the most productive crop plant is by no means as simple as most of our agricultural experts have assumed. We are all aware that the plant breeder can modify any existing variety and breed into it new qualities or breed out of it undesirable qualities. There has been rather too much of a disposition to accept this power of modifying varieties like a gift of manna from Heaven and to assume that mere selection and simple breeding are all that is needed to bring our crop plants up to the maximum of efficiency. Nothing could be farther from the truth.

Three centuries of botanical exploration carried out in the interest of science by self-sacrificing men, often working under the greatest difficulties, have revealed the existence of thousands, yes, tens of thousands of plants either directly useful to man or closely related to species already in use.

Any really intelligent and effective attempt to breed superior varieties of crop plants must be preceded by a botanical survey of the related wild material with a view to securing the best possible forms to work with in attempting such amelioration. If a crop plant shows some marked deficiency, some obvious inability to adapt itself to the climatic and soil conditions of the regions where its culture is attempted, the earth should be scoured for related types of plants which can be used to supply the deficiency. Resistance to cold, to heat, to drought, to insect and fungous enemies, or to a hundred and one unfavorable climatic conditions can often be secured by hybridizing our crop plants with skillfully chosen wild forms and then systematically improving the hybrid offspring by modern methods of plant breeding.

The most efficient improvement of our crop plants and the most effective utilization of the wild types for this improvement necessitates a knowledge of the climatic and soil requirements of the crop plants themselves. Increased knowledge of such facts often leads to unexpected results. For instance, many of the sorghums are well known to be more drought resistant than Indian corn. However, a study of the life history of sorghums reveals the fact that the zero point of growth of the young seedling is relatively very high and in consequence sorghum can not be planted as early in spring as corn, but must be sown in most parts of the West a month or more later. This sometimes causes the young sorghum to be exposed to severe drought before it is old enough and has sufficient depth of root to be able to withstand such exposure. In other words, it is probable that the drought resistance of sorghum may be materially increased by securing races of sorghum which through being native to northern latitudes or through centuries of culture in cold regions have acquired the power of germination at low temperatures. A lowering of the

zero point of growth of the young seedling might easily have a profound effect on the drought resistance of sorghum as a crop.

Here we can see the distinction between crop physiology and plant physiology. Crop physiology is the application of the principles of plant physiology to the production of crops in a profitable and efficient manner. The plant physiologist who is studying drought resistance would be very little interested in the temperature requirements for germination of the plants he is working with. The crop physiologist, on the other hand, who is attempting to discover methods of growing a profitable crop in dry regions might find it a matter of the utmost importance to investigate these thermal relations which at first thought seem to have no bearing on the problem at hand. This study of plant-life history or crop physiology gives a point of view which, when carried over into botanical exploration, enables us to select with more discriminating judgment those wild types of plants best adapted for use in improving our cultivated crops.

A NEW BRANCH OF ECONOMIC BOTANY.

This brings us to the point where we can appreciate the need of developing a new branch of botanical study of the morphological and physiological characters of the wild plants related to our cultivated crops with a view to determining their relationships and their availability for use in the improvement of our crop plants. Many of our agricultural investigators think of botany as a science of plant names or laboratory experiments with little or nothing in the way of practical relations to agricultural problems, but for the most efficient improvement in crop plants we must look to this new branch of botany for a thorough survey of the wild relatives of our cultivated plants. The crop physiologist must investigate the life history not only of the crop plant itself but of its wild relatives before he can begin to understand the possibilities of applying botanical science to agricultural problems.

The necessity of a knowledge of this new economic botany and crop physiology for the proper improvement of crop plants is strikingly shown in the work of breeding hardy citrus fruits. The first attempt along this line was the crossing of our common orange with the hardy deciduous *Citrus trifoliata* of Japan and China. When in a dormant condition *Citrus trifoliata* can withstand intense cold—temperatures of 10° or even 20° F. below zero do not affect it—but the fruit is small, very seedy, contains scarcely any juice, and the skin is full of intensely acrid oil. In spite of these drawbacks the first-generation hybrids with the orange have turned out to be of considerable value and constitute a new race of hardy citrus fruits,

which we have called citranges and which are adapted to culture throughout most of the cotton belt. They will provide a home-grown substitute for lemons for 10,000,000 people of the South.

Life-history study has brought out the fact that the hardiness of the hybrids (citranges) of *Citrus trifoliata*, like that of most other plants, is dependent on their condition when exposed to cold. An interval of hot weather in early spring forces these hybrids into a tender growth and they are then liable to frost injury. In the meantime investigations have shown that the kumquat possesses to a high degree another kind of hardiness due to extreme dormancy in winter; in other words, the kumquat can support weeks of hot weather without starting into new growth. Here, then, we have two kinds of hardiness existing in separate plants—the ability to resist extreme cold in *C. trifoliata* and the ability to withstand untimely spells of hot weather in the kumquat. When these facts were brought out the breeding problem was greatly simplified. It became obvious at once that the use of the kumquat in hybrids would give us plants able to resist injury from hot weather followed by frosts. The latest creation in the way of hardy citrus fruits made by following up this lead is the limequat, obtained by crossing the common West Indian lime with the kumquat.

The lime is known to all growers as the tenderest of all the citrus fruits. Lime trees are frequently frozen to the ground when oranges and even lemons escape with little injury. This is due to extremely slight dormancy, even a few days of warm weather in winter being sufficient to start a new growth, which is then nipped by the first succeeding frost. The kumquat is admirably adapted by its physiological constitution to remedy this defect, and fortunately its fruit, like the lime, contains an agreeable acid juice, and instead of having a disagreeable oil in the peeling, like *Citrus trifoliata*, the oil of the kumquat is so mildly flavored that the peeling is edible, having a pleasantly aromatic flavor.

Thus plant life history investigations pointed the way to a breeding experiment which was carried out in the spring of 1909. Already the hybrids made at that time have fruited abundantly and have fully met our expectations. The limequat proves to be a new race of limes able to grow without protection in extreme northern Florida and probably suitable for culture throughout the warmer parts of the Gulf coast.

The fruits vary in size from that of a large kumquat to that of a small lime, and their flavor varies from mildly acid to as acid as the sourest lime. Here we have a new race of hardy fruits admirably adapted to our own conditions obtained by combining two fruits having very unlike life-history requirements; one of them but poorly

adapted to our climate, the other producing a fruit of little commercial value.

The great value of the kumquat for breeding purposes having been brought out by these experiments, a thorough botanical survey of all the wild relatives of our citrus fruits was undertaken in the hope of finding other plants which, like the kumquat, would be of importance to the breeder. The result of this botanical survey was most surprising. It has brought to light a large number of wild relatives of our common citrus fruits which have been completely ignored by horticulturists and but little understood by botanists.

Recently attention has been directed to a desert kumquat growing in the interior of Australia. This is the hardiest of all the evergreen citrus fruits and yields in the wild state an edible fruit something like a kumquat. This desert kumquat, in addition to the extreme dormancy possessed by the ordinary kumquat, has also something of the direct cold resistance of the trifoliate orange. Here, then, is material of the very highest value for the plant breeder. Yet this desert kumquat is a plant so insignificant in its wild state as to have been completely ignored by the enterprising and progressive Australian horticulturists and of so little interest to botanists that it has never been correctly classified, has never been figured, and has been only imperfectly described. Numerous other types of citrus fruit equally striking as examples of breeding possibilities and botanical neglect have come to light, but it would take too much space to enumerate them here.

MORE EFFECTIVE PLANT BREEDING.

A combination of this new kind of economic botany with crop physiology would greatly increase the efficiency of the art of breeding. I can do no better than compare the ordinary plant breeder to the man who attempts to paint a picture with a few colors picked up at random and the scientific plant breeder to the consummate artist who paints a masterpiece having at his disposal all the tints that art can offer. The really enlightened and efficient plant breeder must know his materials and what they are capable of yielding.

We must remember that it is unfair to expect the technical taxonomic botanist to have any very keen interest in the obscure relatives of our cultivated plants. Often the general relationships of these plants are known, and it does not seem worth while to expend much time or money in the attempt to secure more complete material of plants which promise no results of taxonomic importance. For the purposes of effective plant breeding, however, these obscure wild relatives, through some physiological peculiarity of insignificance to the taxonomist, may be of vital importance in the work of improving some great crop plant in the cultivation of which hundreds of thou-

sands of people are engaged and which furnishes subsistence for millions of human beings. Without any question, the wild relatives of our cultivated crop plants are destined to receive a most thorough overhauling. Even the most obscure of them must be secured, studied, put under culture, and made available for the student of this new botany and for the crop physiologist.

AGRICULTURAL EFFICIENCY THROUGH SOCIAL PRESSURE.

Thus far we have considered the problem of the improvement of our crop plants from the standpoint of the plants themselves, with the object of placing in each locality the types of plants best adapted to the climate and soil of the region. There is another equally, if not more important principle to be considered, namely, that of the proper education of the men who are to grow these plants. It is becoming increasingly evident that the problems of modern agriculture require the education not merely of the individual farmer, but of the whole community. The most efficient crop cultures are those carried on by communities where many people are interested in crop problems and where there is what might be called a social pressure tending to maintain a high standard of excellence on the part of the workmen, as well as of the owners themselves. This may be illustrated by the problem of orange or apple culture or any other highly developed fruit industry. If a man with only a general knowledge of the subject buys an orchard in the region where these cultures are being carried on in an extensive way, he finds it very easy to catch the spirit of the work and to develop critical judgment and high efficiency. Even more, the very workmen themselves are permeated with the spirit and are kept up to a high standard for fear of ridicule on the part of the other workmen in the community. In other words, the whole community acts as a unit, and new workmen as well as new proprietors are rapidly whipped into line and taught the elemental lessons of efficiency. How different the condition where a man attempts to maintain a highly developed fruit industry in some backward eastern community, for instance, where he is looked upon by the old settlers as a man with new-fangled ideas and meets with the silent contempt and stubborn resistance of his workmen, who are persuaded that the old-fashioned methods to which they are accustomed are better than his new and perhaps more effective ones. It is very difficult for such a man to maintain a high degree of efficiency and to secure and keep capable workmen.

Organized community action has long been recognized as essential in the proper marketing of agricultural products, and its advantages are very obvious in the purchase of fertilizers and machinery and in the organization and maintenance of irrigation districts and other

community enterprises. Sufficient emphasis has not, however, been placed upon the absolutely vital part played by the community spirit in the maintaining of a high degree of efficiency in crop production and improvement. There can be little doubt that our American civilization is very well adapted to the development of this community spirit. It has reached a high degree of development in the Far West, where it was first rendered necessary in order to secure water for irrigation purposes.

The agricultural progress of the twentieth century will undoubtedly result in the occupation of the now neglected East by picked and efficient communities of settlers from the West, who will buy up whole political units, townships, or counties, and displace the present population. In many cases the individuals who compose the eastern communities may be as efficient as their western competitors, but no amount of individual ability can compensate for the lack of a community spirit.

Here, then, are in brief the fundamentals of crop improvement:

A new botanical survey of the wild relatives of our crop plants.

A crop physiological study of the capacities and limits of this material.

The creation of new and more efficient types of crop plants, utilizing the facts brought to light by the new botanical and physiological investigations.

Finally, the effective utilization of these crops by communities in which the high level of efficiency is maintained by an awakened public opinion.

THE AGRICULTURE OF THE FUTURE.

It is now obvious that the improvement of our crop plants and the efficient organization of the communities that grow them is rapidly passing beyond the power of any one man, no matter how competent he may be. The scientific study of the fundamentals of crop improvement require the efficient cooperation of a number of men having different points of view and different kinds of ability. In other words, something analogous to the community organization is essential among the investigators themselves, in order that a higher order of efficiency may be secured. The one-man stage of investigation is rapidly passing and with it the military type of organization which has acted as a barrier to complete freedom of discussion so essential for the development of all-round critical judgment.

Projecting ourselves a few years into the future we see before us the great problems of agriculture being attacked from radically new points of view. Committees of experts who by training and experience have learned to work harmoniously and effectively in cooperation will take up one by one the great crop plants of the world, transforming and improving them, and will assume the leadership in organizing the communities where these crops are to be grown. As soon as efficient communities of producers exist there will come to be

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the closest cooperation and exchange of ideas between these committees of experts and the leaders of communities. This will be the final and highest stage of agriculture, which will result in a scientific organization for each of the great crop plants, keeping not only the crop plants themselves but the experts who study them and the communities of farmers who grow them on the highest plane of efficiency.

It is obvious from what has been said that the agriculture of the future will require an intellectual alertness, sustained interest, and business ability which a great many farmers do not now possess. It is no exaggeration to say that modern biology, which is the background of agriculture, is influencing country life as profoundly as electricity has influenced industrial life, and herein lies the hope of the agriculture of the future. This biological background is a realm of fascinating interest, and an appreciative understanding of the facts of nature will not only lead to greater efficiency in agricultural production, but will give that essential mainspring of interest which will make country life agreeable and interesting to a fair proportion of the brightest minds of the country. Country life can not permanently be successful unless men of great ability live in the country and are of the country. Our present civilization tends automatically to drain intelligence to the great cities. The most important conservation is the conservation of human intelligence and the most important indirect advantage of this new agriculture lies in the fact that it points out the means of utilizing in everyday life the wonderful facts of nature placed at our disposal by modern biology.

THE WORK OF THE SCOTTSBLUFF EXPERIMENT FARM IN 1912.[1]

By Fritz Knorr, *Farm Superintendent, Office of Western Irrigation Agriculture.*

INTRODUCTION.

The experiments conducted at the Scottsbluff Experiment Farm[2] are confined chiefly to the various crop and cultural tests under irrigation, but about 30 acres are reserved for dry-land experiments. The dry farming is conducted by the Office of Dry-Land Agriculture of the Bureau of Plant Industry and is confined to crop rotation and tillage experiments and the testing of some of the dry-land crops to determine their adaptability to conditions in western Nebraska.

The experiments under irrigation include crop rotation, cultivation, methods of irrigation, the growing and testing of various crop varieties in order to determine those best adapted to the local conditions, and the testing of shade and fruit trees and of small fruits and shrubs (fig. 1).

During the year 1912 there were 662 plats on the farm, the size of the plats ranging from one-fourth acre to row tests for corn, sorghum, etc. Considerable land was devoted to the growing of trees from seeds and cuttings. Vegetables were also tested in a limited way in order to determine the best varieties for the locality.

CLIMATOLOGICAL OBSERVATIONS.

The climatological observations at the farm are made in cooperation with the Office of Dry-Land Agriculture and the Biophysical

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[1] Issued Mar. 8, 1913.

[2] The Scottsbluff Experiment Farm is located on the North Platte Reclamation Project, 6 miles east of Mitchell and about 8 miles northwest of Scottsbluff, Nebr. The tract consists of 160 acres of land irrigated from the Government canal. Though the entire tract is irrigable, about 30 acres are devoted to dry-land experiments. The land was withdrawn from entry by the Department of the Interior for use as an experiment farm, and operations were begun in 1909. Three of the original buildings were erected by that Department. The farm is under a superintendent detailed by the Office of Western Irrigation Agriculture, U. S. Department of Agriculture. The work is supported by Federal appropriation through the Department of Agriculture and by State appropriation through the University of Nebraska. The buildings on the farm outside of the original three structures have been erected from State funds.

Laboratory of the Bureau of Plant Industry. The necessary apparatus is furnished by the Biophysical Laboratory.

Table I summarizes the results of the climatological observations made during 1911 and 1912.

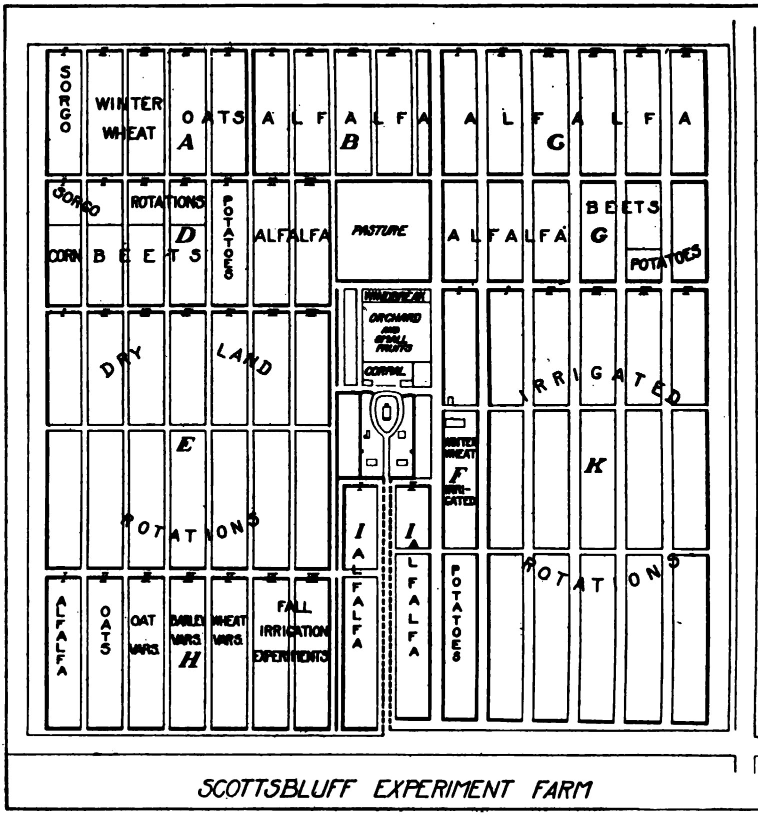

FIG. 1.—Sketch of Scottsbluff Experiment Farm, showing the locations of the various crop experiments in 1912. The farm consists of 160 acres. In 1912 it was divided into 662 experiment plats.

TABLE I.—*Summary of climatological observations at the Scottsbluff Expreiment Farm in 1911 and 1912.*

PRECIPITATION (INCHES).

Year and kind of data.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1911	0.45	0.10	0.00	2.31	0.81	2.13	1.28	0.65	2.14	1.10	0.08	0.34	11.39
1912	.20	.60	1.27	3.72	1.66	1.61	2.45	2.77	2.70	1.16	.37	0.00	18.51

TABLE I.—*Summary of climatological observations at the Scottsbluff Experiment Farm in 1911 and 1912*—Continued.

EVAPORATION (INCHES).

Year and kind of data.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1911	......	......	......	5.54	7.15	8.90	9.08	7.43	6.18	......	......	......	44.28
1912	......	......	......	4.24	7.14	6.64	6.67	6.32	4.16	......	......	......	35.17

DAILY WIND VELOCITY (MILES PER HOUR).

Year and kind of data.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1911, mean	6.1	6.4	7.8	8.4	8.8	6.0	5.2	5.4	5.4	5.9	6.8	4.9	....
1912, mean	5.4	5.7	6.7	8.6	8.1	5.4	4.0	4.2	5.0	5.0	4.3	6.4	....
1911, maximum	15.9	13.7	15.8	14.6	15.2	10.8	8.4	9.2	11.1	12.2	15.6	8.4	....
1912, maximum	12.4	14.7	15.3	31.4	16.6	15.9	6.0	7.0	11.5	10.8	12.6	15.8	....
1911, minimum	1.7	2.1	3.0	3.6	4.8	3.0	3.1	2.6	2.9	2.5	1.9	1.2	....
1912, minimum	1.6	1.4	2.7	3.2	2.9	1.6	2.0	2.6	2.4	2.0	1.1	1.3	....

MONTHLY TEMPERATURE (DEGREES FAHRENHEIT).

Year and kind of data.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
1911, mean	29	27	42	45	46	70	69	68	64	43	32	24	....
1912, mean	20	24	21	45	55	63	69	67	52	47	39	27	....
1911, maximum	68	64	74	80	88	95	94	98	93	78	66	62	....
1912, maximum	53	50	55	73	87	93	91	96	89	83	71	56	....
1911, minimum	−19	−7	11	11	22	42	40	41	38	11	−12	−11	....
1912, minimum	−21	−14	−15	25	30	39	47	44	22	12	3	1	....

KILLING FROSTS.

Years.	Last in spring.		First in autumn.		Length of frost-free period, days.
	Date.	Minimum temperature.	Date.	Minimum temperature.	
		°*F.*		°*F.*	
1911	May 26	28	Oct. 3	31	129
1912	May 14	30	Sept. 16	31	124

CONDITIONS ON THE PROJECT.

The land irrigated under the North Platte Reclamation Project includes only a part of the irrigated land along the North Platte River in western Nebraska and eastern Wyoming. Certain private irrigation companies are providing water for land on both sides of the river, and some lands have been irrigated for many years. Table II gives statistics on crop acreages and yields, which apply only to land under the reclamation project, and not to the older lands. The data for this table have been furnished by the Reclamation Service.

In 1912 there were 827 irrigated farm units on the North Platte Reclamation Project, having a total irrigable area of 67,080 acres. Of this area, 50,250 acres were actually irrigated, and 47,251 acres were in crops that were harvested. Table II shows the distribution of this acreage among the various crops enumerated and the yields and farm values of these crops.

TABLE II.—*Acreage, yields, and farm values of crops grown on the North Platte Reclamation Project in 1912.*

Crop.	Area.	Yields.				Farm values.			
		Unit.	Total.	Per acre.		Per unit of yield.	Total.	Per acre.	
				Average.	Maximum.			Average.	Maximum.
	Acres.								
Alfalfa hay	19,512	Ton	42,604	2.2	4.0	$5.00	$213,020	$10.92	$20.00
Alfalfa seed	1,174	Bushel	977	.8	2.5	9.00	8,793	7.49	22.50
Barley	1,156	...do...	31,064	27.0	60.0	.50	15,532	13.44	30.00
Corn	6,260	...do...	96,821	15.0	50.0	.40	38,728	6.19	20.00
Oats	10,093	...do...	295,360	29.0	105.0	.35	103,376	10.24	36.75
Potatoes	1,192	...do...	121,392	102.0	450.0	.25	30,348	25.46	112.50
Rye	996	...do...	8,700	9.0	22.0	.50	4,350	4.37	11.00
Sugar beets	667	Ton	7,132	11.0	24.0	5.60	39,939	59.88	134.40
Wheat	4,390	Bushel	75,354	17.0	44.0	.67	50,487	11.50	29.48
Miscellaneous	1,811						16,882	9.32	
Total	[1] 47,251						521,455		
Average value per acre								11.04	

[1] Of the acreage shown here, 9,931 acres was in 1912 seeded to alfalfa, with nurse crops of wheat, oats, or barley, the grain yields of the nurse crops being included under the headings of wheat, oats, and barley, respectively. An area of 2,999 acres of alfalfa was also seeded without a nurse crop, from which no yields have been reported. This area added to the 47,251 acres shown in the table makes the total area of 50,250 acres actually irrigated.

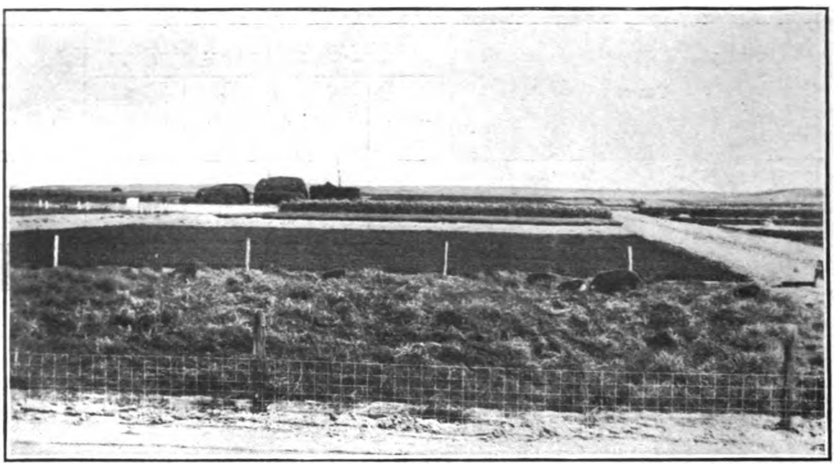

FIG. 2.—Plats occupied by rotation 65, which consists of corn, flax, oats, and three years of alfalfa. The corn and the third-year alfalfa are pastured off by hogs.

EXPERIMENTS WITH IRRIGATED FIELD CROPS.

ROTATION OF CROPS UNDER IRRIGATION.[1]

In order to determine the relative values of different crop sequences for local irrigated conditions, eighty ¼-acre plats are devoted to crop-rotation work. On these plats 31 rotations are carried, including alfalfa, sugar beets, corn, flax, oats, potatoes, and wheat, which are

[1] These experiments are under the direct supervision of Mr. James A. Holden, assistant.

the field crops most commonly grown under irrigation in western Nebraska (fig. 2).

As this work has been in progress only one year, no significant results have yet been secured. The average yields per acre obtained in 1912 were as follows: 20 plats of first-year alfalfa, 2.62 tons; 14 plats of sugar beets, 17.11 tons; 5 plats of corn (Calico variety), 56.1 bushels; 2 plats of flax (South Dakota variety), 26.6 bushels; 18 plats of oats (Colorado No. 13), 96.2 bushels; 13 plats of potatoes (Pearl), 226.8 bushels; and 6 plats of spring wheat (Defiance), 46.2 bushels. Some of these same varieties were included in the variety tests on another part of the farm, the yields, in bushels per acre, being as follows: Calico corn, 43.2; Colorado No. 13 oats, 100; Pearl potatoes, 615; and Defiance wheat, 49.7.

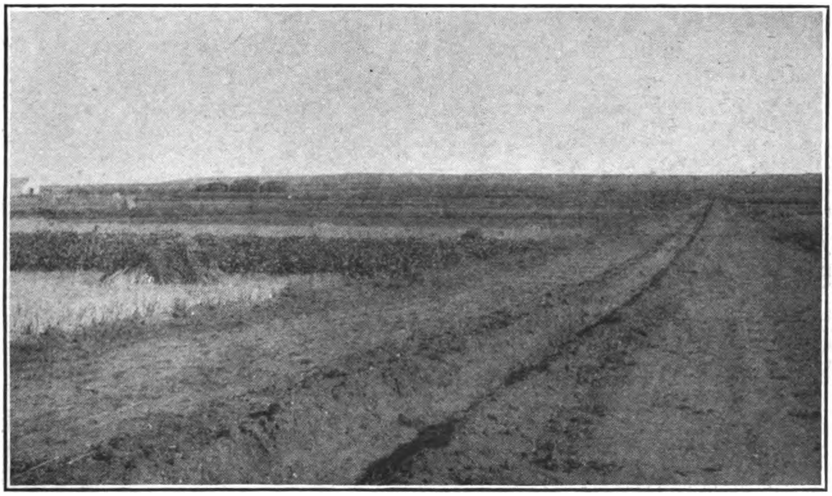

FIG. 3.—A general view of field K, where the irrigated rotation experiments are conducted. The irrigation ditch is 20 feet from the ends of the plats, making it possible to cultivate the plats without damaging the ditch banks.

LATE SEEDING OF ALFALFA IN OAT STUBBLE.

The common practice of seeding alfalfa in the spring frequently results in failure to secure a satisfactory stand. Where the crop is seeded with a nurse crop of wheat or oats, the growth of the nurse crop is often so dense as to prevent or seriously retard the proper development of the young alfalfa plants. Frequently, also, spring-seeded alfalfa suffers greatly from soil blowing, which is most severe in the spring.

In three of the rotations on field K (fig. 3) the plan is to have alfalfa follow oats, and it was decided to test late summer planting of alfalfa in these rotations. The land preparation consisted of double disking and harrowing after the removal of the oat crop.

The alfalfa was planted August 20. When the alfalfa is to be planted on very sandy soils, disking is not generally advisable, as it increases the likelihood of soil blowing. Satisfactory stands and root growth were obtained, and the crop went into the winter in good condition.

WHEAT VARIETIES.

During the past two years, 9 varieties of spring wheat have been grown, one plat only to each variety. Of these 9 varieties, 4 are of red wheat, 4 are of white, and 1 is of the durum type. The durum wheat has been discarded, as there is no local market for it. The highest average yield for the white wheat during the two years was obtained with the Defiance, which produced 39.8 bushels per acre.

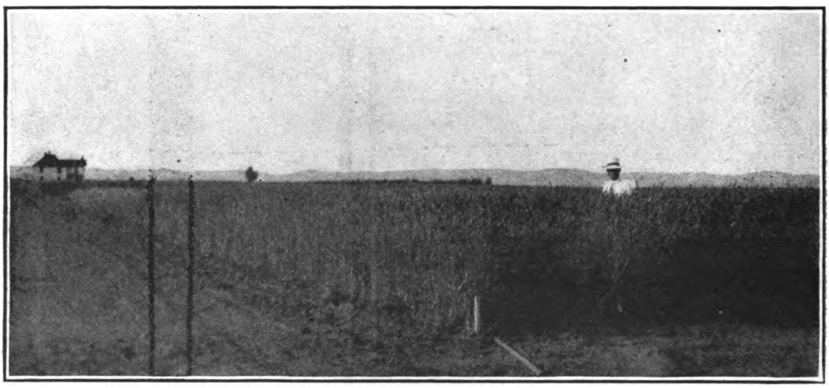

FIG. 4.—A plat of Defiance wheat in the irrigated rotations. This plat yielded at the rate of 52.5 bushels per acre. The average yield of the six wheat plats in the irrigated rotations was 46.2 bushels per acre. The Defiance averaged highest in the wheat variety tests in 1911 and 1912.

In 1912 the same variety yielded 49.7 bushels per acre in the variety test and as high as 52.5 bushels per acre in the rotation experiments (fig. 4). The highest yielding red wheat was the Bluestem, which averaged 37.5 bushels per acre.

OAT VARIETIES.

Eight varieties of oats have been tested for two years, one plat to each variety, all of them being of the open-panicle type. Seven of these are white and medium early; one, the Sixty-Day or Kherson, is yellow and early maturing. In the variety tests, the highest yielding variety of white oats is the Colorado No. 37, which averaged 66.3 bushels per acre for the two years. The Sixty-Day, or Kherson, averaged 58.5 bushels per acre. The difference in the time of ripening of the early and the medium early was 12 to 16 days.

This is a matter of much importance in sections that are visited by hailstorms annually, the early-maturing varieties being more likely to escape damage.

BARLEY VARIETIES.

Fourteen varieties of barley were tested in 1912—one plat to each variety. Six of these are 6-rowed, three 2-rowed, five hooded (four bald and one beardless). The bald barleys weigh 60 pounds to the bushel. The best yield secured with these was 39.2 bushels, the yield produced by G. I. No. 262. The yield of the hooded barley was 40.2 bushels per acre, weighing 48 pounds to the bushel. The highest yielding 6-rowed barley was the California Feed, which produced 70.6 bushels per acre. Imported Franconian, No. 680, a 2-rowed type, was second in yield, producing 68.3 bushels per acre.

CORN VARIETIES.

Twenty-three varieties of corn were grown in 1912 with a view to finding a good early-maturing variety adapted to the short season, in order eventually to carry on some special seed-selection work to improve that particular variety. Four of the varieties tested were of the flint type; the remainder were dents. No recommendation can be made at this time regarding varieties, except that farmers should not secure seed from localities east of North Platte, Nebr.

The flint corn matured better than the dent corn. The highest yields were 53.6 bushels per acre for the flint varieties and 50.3 bushels per acre for the dent varieties. The objection to the flint is that it forms the ear low down on the stalk and is difficult to harvest. The average yield of the 23 corn varieties was 43.3 bushels per acre.

SORGHUM VARIETIES.

A number of saccharine and nonsaccharine sorghums were grown in 1912. Although all of them made a good growth, none of them matured seed. The advisability of growing the nonsaccharine sorghums, such as kafir and milo, on the local irrigated lands, where good yields of corn can be secured, is very doubtful.

POTATO VARIETIES.

The potato variety test of 1912 was the most extensive on the farm. It included 13 of the old established varieties and 50 seedlings. The best yield was obtained with the Pearl, which yielded 615 bushels per acre. Of these, 95.4 per cent were marketable tubers, as determined by passing them over a 2-inch screen. The best medium-season variety was the Eureka, which yielded 476.6 bushels

per acre, of which 95.1 per cent were marketable tubers. It has been found that such varieties as Somer's Early, Early Rose, Early Manistee, and Burbank are not adapted to local conditions and produce a tuber that is not marketable. Of the seedlings grown, about 10 seem to be very promising; the others have been discarded.

METHODS OF IRRIGATION AND CULTIVATION OF POTATOES.

The work on methods of irrigation and cultivation was carried on in cooperation with the Office of Horticultural Investigations of the Bureau of Plant Industry. Potatoes were planted on three different soils—alfalfa sod, stubble, and fallow land. On each of these soils the following work was conducted in duplicate plats: Twelve plats were deep cultivated and deep ditched for irrigation, and 12 plats were shallow cultivated and shallow ditched. In each case on two plats alternate rows were irrigated throughout the season; on two plats every other row was irrigated; two plats were irrigated so that the plants should never lack moisture; three check plats were irrigated in alternate rows, but not until the plants showed actual need of water.

The largest yield was obtained on alfalfa land, where alternate rows were irrigated under the shallow cultivation and ditching. In all cases the alfalfa sod produced the largest yields and the stubble land the lowest yields. The percentage of culls on the stubble land ran from 50 to 75 per cent higher than that on the alfalfa sod.

FIELD PEAS.

Several varieties of field peas were grown in cooperation with the Office of Forage-Crop Investigations of the Bureau of Plant Industry. The highest yield was 23.5 bushels per acre, which was produced by the variety S. P. I. No. 11200. The lowest yield was 11 bushels per acre. The average yield of the seven varieties was 16.9 bushels per acre. Unless higher yields can be secured it will not be profitable to grow peas for feeding purposes on these high-priced irrigated lands.

FALL IRRIGATION.

During the past two years experiments have been conducted to determine the value of irrigating land in the fall and letting it go into the winter wet. The test has been applied to sugar beets, potatoes, wheat, oats, barley, and corn (fig. 5). In both years the sugar beets were a partial failure, owing to blowing out in the spring. The first year the potato crop was a failure, due to diseases.

The average yield of wheat on the fall-irrigated land was 36.4 bushels per acre, as against 30.4 bushels on land not fall irrigated,

a difference of 6 bushels per acre. With oats the average yield on the fall-irrigated land was 81.5 bushels per acre, and only 65.7 bushels on land not fall irrigated, a difference of 15.8 bushels in favor of fall irrigation. The barley yielded an average of 40.1 bushels per acre on fall-irrigated land and 28.5 bushels per acre on the land not fall irrigated, the difference being 11.6 bushels per acre. On account of the beets having been blown out and having to be reseeded, the yield was very small, the average for fall irrigation being 13.3 tons per acre, against 12.6 tons for land not fall irrigated. The yields of corn and potatoes were about even for the two methods, the difference being so small that it can not be attributed to irrigation.

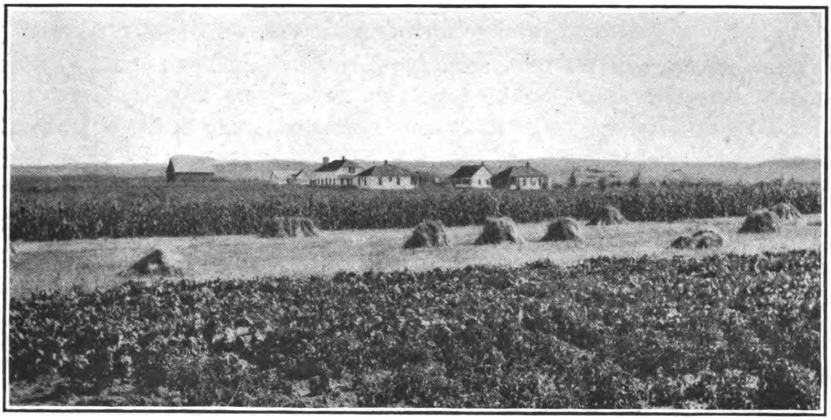

FIG. 5.—Plats used in the test of fall irrigation. This test included potatoes, sugar beets, wheat, oats, barley, and corn. The fall irrigation of the land increased the yields of all these crops except corn and potatoes.

SUGAR BEETS.

The work with sugar beets has included tests of depth of plowing, cultivation methods, time of irrigation, and distance of thinning. The plats were plowed, respectively, 4, 8, 12, 16, and 20 inches deep. The deepest plowing gave the lowest yield and the shallow plowing the highest. The previous crop on this soil was sorghum. The cultivation no doubt left the soil in a better and looser condition than it would have been if an untilled crop had been grown. This doubtless accounts in part for the much higher yield of the shallow breaking. The yield of the land plowed 4 inches deep was 20.5 tons per acre, as compared with 16.5 tons for the land plowed 20 inches deep.

Cultivation of beets.—Three methods were followed: Deep cultivation at first and shallower at each succeeding cultivation, 3-inch cultivation throughout the season, and shallow cultivation throughout the season. The yields obtained were, respectively, 17.6, 16.6,

and 18.8 tons per acre. The results slightly favor shallow cultivation, though the differences are scarcely significant.

Irrigation of beets.—The methods followed were (1) the usual irrigation, (2) irrigation as the soil requires water to keep it moist throughout the season, (3) irrigation at intervals so that the plants suffer for water before it is applied, and (4) delay of the first irrigation until the plants begin to suffer for water, and then irrigation by the common method. The yields of the beets were 16.5, 15.9, 16.6, and 17.4 tons per acre, respectively. On account of the excessive rainfall during the growing season, the results are not significant.

Distance of planting beets.—Sugar beets were planted in rows 18, 20, 24, and 28 inches apart. In each of the plats the plants were thinned to 6, 9, 12, 15, and 18 inches apart in the rows, respectively. The highest yield was obtained from rows 28 inches apart, with the plants 9 inches apart in the row, the yield being 18.5 tons per acre. The second highest yield, 18.3 tons per acre, was obtained from 20-inch rows, with the plants 9 inches apart in the row. Greater distances than 20-inch rows, with the plants 9 inches apart in the row, are not recommended, as the beets are likely to be large and overgrown, and require more labor to harvest. The 18-inch planting makes working in the beets more difficult, especially the cultivation and irrigation.

ORCHARD AND SMALL FRUITS.

The severe conditions of the winter of 1911–12 did much damage to the orchard trees. Many of the tender varieties were killed and some of the more hardy varieties were severely injured. Only those fruit varieties which are relatively hardy can be expected to succeed under the rigorous winter conditions on the project. It has been found that windbreaks can be made to furnish considerable protection to orchard trees, and the presence of good, strong windbreaks is one of the essentials of successful fruit growing. Numerous small additions were made during the year to the variety tests of orchard trees and bush fruits.

In tests conducted to determine the most satisfactory time to plant strawberries the best results have been obtained from late summer planting. It has been found much better to plant from August 1 to 15 than at any time during the spring.

TREES AND ORNAMENTALS.

During the year about 5,000 cuttings of several species of trees and shrubs were set out in the nursery rows and a large number were grown from seeds. A windbreak was set out on the north and west sides of the orchard, and it made excellent growth. A large number

of hardy trees and ornamental shrubs were planted on the grounds around the farm buildings. All these made satisfactory growth except the evergreens, which failed to start.

For windbreaks and shade trees the following species have shown promise: Poplar, cottonwood, elm, ash, hackberry, and the white, Russian golden, and laurel-leaf willows. For ornamental shrubs the following are promising: Van Houte spirea, snowball, common and Siberian dogwood, *Rosa rugosa*, common and golden elder, high-bush cranberry, common, purple, and Japanese barberries, the flowering currant, and the hydrangea.

GARDEN VEGETABLES.

Tests have been conducted with most of the common garden vegetables. All those which have been tried have been found to grow satisfactorily. It has been found that only the early-maturing varieties of tomatoes and melons should be planted on the project. Sparks's Earliana has proved the most desirable of the tomatoes tested. Early Jersey Wakefield is the most promising of the early-maturing varieties of cabbages, and Danish Ball Head is the best late-maturing cabbage tested. Golden Hubbard and Improved Hubbard squash have both done well. Good yields have been obtained with the common varieties of summer squash and cucumbers.

THE HIMALAYA BLACKBERRY.[1]

By H. P. Gould, *Pomologist in Charge of Fruit District Investigations.*

INTRODUCTION.

During the past year or two numerous inquiries regarding the Himalaya blackberry have reached the Bureau of Plant Industry, with special reference to claims of remarkable productiveness and a very wide range of adaptability that have been made for the variety. The following notes are therefore published for the information of those who are interested in this plant.

Though the Himalaya blackberry is closely related to our common blackberries and dewberries its exact botanical identity does not appear to have been determined. In habit of growth the plants are like the dewberry in that the canes are perennial and do not die each year after the fruiting period, as is the case with the common blackberries and raspberries.

The Himalaya blackberry was grown by Mr. Luther Burbank from seeds received by him about 1889 or 1890 from a friend who stated that they had been gathered high up on the Himalaya Mountains. Mr. Burbank disseminated it on the Pacific coast about 1894 under the name "Himalaya Giant," though he had listed it as "an improved variety of *Rubus sp. Himalaya*" in his catalogue for 1893. He advised the Bureau of Plant Industry in 1905 that he had not included this variety in his general catalogue for the reason that he was afraid that it would not prove hardy everywhere the catalogue was sent, and so he introduced it by means of a special circular mailed only to parties on the Pacific coast and in the South.

BEHAVIOR OF THE VARIETY IN THE EAST AND SOUTH.

Following the reported success of this berry in the Puget Sound region of Washington, the Department of Agriculture in February, 1906, secured 200 plants of the variety for distribution, with a view to determining its relative hardiness and its adaptability to culture in sections east of the Rocky Mountains. The plants were obtained from the Albany Nursery Co., of Albany, Oreg., their authenticity

[1] Issued Mar. 8, 1913.

being certified by the company in a statement to the effect that their original stock of this variety was secured directly from Mr. Burbank. The plants were distributed under S. P. I. No. 17473 by the Office of Foreign Seed and Plant Introduction to growers in many representative sections of the country east of the Rocky Mountains.

REPORTS OF COOPERATORS.

Early in 1911 reports concerning the behavior of the variety under their respective conditions were received from several cooperators to whom plants were sent in 1906. Summaries of these reports follow, the locality from which each one was received being indicated.

New Braunfels, Tex.

Perfectly hardy. An immense grower, covering a large space in a single season after being planted. Plants never showed a sign of a flower nor produced a single fruit. Most troublesome berry plant in the South to control, and considered worthless for this latitude.

Denison, Tex.

Plants as hardy as the Early Harvest blackberry in enduring cold; more resistant to drought. A very strong-growing, sprawling plant; very thorny and unmanageable. Scattering blooms occur over a long season, from which develop a few fruits of medium size, mediocre in quality, and of poor appearance.

This cooperator further reported: "Shall discard it as worthless."

Oneco, Fla.

Low-growing plants like a dewberry; quite vigorous, but has never flowered here.

It was further reported: "We have been disappointed in this and shall have to give it up."

Glen St. Mary, Fla.

They have not made a very rapid growth, but appear perfectly healthy. Up to this time they have not fruited, and we are unable to make any statement regarding their merits.

This report is based on five years' observation of the plants.

Homeland, Ga.

At this place it was considered a success.

Ocean Springs, Miss.

Apparently hardy here, where also Snyder and Early Harvest blackberries are hardy. Growth very rank in comparison with the common blackberry varieties, but absolutely barren. Not considered more difficult to manage than the trailing types of blackberries and dewberries.

Fayetteville, N. C.

Plant hardy, growth medium; size of fruit perhaps medium, but defective in shape; color dull, dark; only fairly productive. Season late.

Geneva, N. Y.

Here it is considered less hardy than the Early Harvest and Snyder blackberries; 100 per cent more vigorous and more troublesome to control than other vigorous varieties; less productive. Slightly later, but much longer in season. Size larger, flavor more acid, quality inferior in comparison with these varieties.

Spring of 1907, canes showed some winter injury. Spring of 1908, 75 per cent or more winter injury to the canes. Growth very rank during season of 1908. Some bloom, and plants appeared to be productive. In November of that year plants were removed from trellis and protected during winter. Season of 1909 was unusually long; fruit good size and color, but not equal in flavor or quality to best commercial varieties of blackberries.

South Haven, Mich.

As hardy here as the Snyder blackberry; very much more vigorous than any other bramble; more sprawling in habit of growth than any other bramble, except the dewberries; not as productive as Snyder or Early Harvest. Size, flavor, and general appearance of the fruit very poor; generally small and "nubby" and of no market value; later in season than most of the other very latest blackberries. Considered of value only where other varieties can not be grown.

BEHAVIOR AT ARLINGTON FARM AND ELSEWHERE.

Some of these plants were grown at the Arlington Experimental Farm, which is maintained by the Bureau of Plant Industry, near Washington, D. C. At the time the foregoing reports were made the superintendent of the farm reported as follows:

Very hardy; very rapid and profuse grower; not very productive; 7 to 10 days later than standard varieties; about one-half the size of Early Harvest and Snyder; equal to them in flavor and quality; extremely vigorous and troublesome to control.

Under date of January 28, 1913, after two additional seasons' experience with this variety at the farm, a second statement regarding its behavior was made, which in substance, follows:

It appears necessary to revise the previous report as to the quality of this fruit. The consensus of opinion at the farm seems to be that it is inferior in quality to the Snyder blackberry. Its productiveness is placed at less than one-half that of the Snyder. The longest cane in the patch measured 26 feet.

A recent report from Ottawa County, Mich., regarding this variety (the plants in this case not having been sent out by the Bureau of Plant Industry) is summarized as follows:

Practically no winterkilling during winter of 1910–11; no question about its vigor; canes grew to a length of nearly 18 or 20 feet in the season of 1910. In 1911 the plants were loaded with fruit, but it was small and mostly "nubbins"; flavor not at all pleasant. In 1912 the fruit on the same plants was much better in size than it was the previous year, but not regarded as superior to that of the standard varieties of blackberries.

CONCLUSIONS.

It will be noted that the statements quoted are generally adverse to this fruit. The one marked exception is the report from Homeland, Ga., which represents it as successful. This report, however, was very brief and gave no information regarding the general behavior of the plants, nor is it apparent what standards of comparison were used.

Prior to the distribution of the Himalaya blackberry by the Department of Agriculture in 1906, it had been tested in Texas. In February, 1906, Mr. F. T. Ramsey, proprietor of the Austin Nursery, Austin, Tex., wrote to this Department as follows:

> I bought some plants of this at 50 cents or $1.50 apiece * * * when * * * first introduced * * *, and I now have a row of them 200 yards long, 5 feet deep and about 20 feet broad. We can not get at the roots of them to cut them off; they would turn a mad bull or a scared cat. Before they bore for me much I sold a few plants, but I have apologized to all who bought them and gave them something else. They are not a success in this atmosphere. They ripen here entirely after the latest blackberry and are very small.

It may be further stated that this berry was planted in 1908 in the fruit garden at the dry-land field station which is maintained by this Department at Akron, Colo. While the canes have killed back considerably nearly every winter, it is by far the most vigorous of any of the brambles planted at that station. It makes a strong, healthy growth and appears to be drought resistant in a marked degree. However, it is absolutely worthless so far as the fruit is concerned. It produces only a few scattering fruits that are the merest "nubbins" in size and form and which ripen over a long period. The quality is so inferior as to make the fruit almost inedible.

In explanation of the conflicting results which have been claimed for this berry from time to time the statement has become more or less current that there are "three different varieties of Himalayas," two of which are not hardy except on the Pacific coast and the fruit of which is inferior. The inference is that the third variety is the one on which the claims for great productiveness, high quality, and wide range of adaptability are based. But the authority for the statement that three varieties have been disseminated under this name appears to be generally unknown, and the statement lacks confirmation.

While this berry appears to be well adapted to the Puget Sound region in Washington and is of commercial importance in portions of California and elsewhere on the Pacific coast, its general usefulness and adaptability to conditions in a large portion of the country east of the Rocky Mountains, as indicated by the reports received, are evidently very restricted. This is not due to insufficient hardiness so much as to nonproductiveness and to the inferiority of the fruit.

THE ARTIFICIAL CURING OF ALFALFA HAY.[1]

By H. B. McClure, *Assistant Agriculturist, Office of Farm-Management Investigations.*

INTRODUCTION.

The need of some means for applying artificial heat to the curing of hay has long been urged and was brought definitely to the attention of the Department of Agriculture some years ago by Mr. T. P. Russell, of Hayti, Mo. In many localities, as in southeast Missouri, alfalfa and other legumes are well adapted as farm crops and produce good yields, but considerable difficulty is usually experienced in curing them, on account of the heavy dew and frequent rains during the haying season. Mr. Russell was formerly a lumberman, and his experience in the use of drying kilns for curing lumber suggested the feasibility of applying similar means to the curing of hay. Experiments in the practical application of this idea have been in progress since the autumn of 1907.

KEEPING QUALITIES AND PALATABILITY OF THE HAY.

The question has often been asked, "Will freshly cut hay covered with dew or rain and containing from 70 to 80 per cent of moisture, cured in from 20 to 40 minutes into hay containing about 10 per cent of moisture, keep if baled immediately or left loose in the barn?" Carefully conducted tests already made have shown that alfalfa hay cured in this manner will keep indefinitely when baled as it leaves the kiln. Loose hay will also keep well; but whether baled or loose it will absorb moisture until it contains about 14 per cent or more.

Horses and mules eat artificially cured hay readily and do not have to be taught to like it. Repeated tests have been made by placing field-cured hay in one part of the manger and kiln-cured hay in the other part. In every instance the animal ate the kiln-cured hay first and often refused to eat the field-cured hay. No extensive feeding test has been made, but it seems practically certain that the results of such a test if made would be in favor of the hay cured by the new process.

[1] Issued Mar. 8, 1913.

REVIEW OF WORK DONE AND IN PROGRESS.

EARLY EXPERIMENTS.

It is well known in the hay industry that the most important factor in grading hay is its color. Preliminary tests to determine the effect of the application of artificial heat to freshly cut alfalfa showed no injury to the color by temperatures ranging as high as 150° to 180° F., and later tests have not only confirmed these results but have shown that temperatures as high as 250° F. may be safely applied under proper conditions.

A chemical examination of the artificially cured hay to determine its feeding value as compared with that of freshly cut alfalfa and of alfalfa cured in the field by the ordinary process and stored in the barn till ready to bale showed that the artificially cured product stands much higher in protein than the field-cured hay. The results of this examination are given in Table I.

TABLE I.—*Chemical analysis of alfalfa hay variously treated.*

Kind of hay.	Moisture.	Ether extract.	Ash.	Crude fiber.	Albuminoids (N×6.25).	Nitrogen-free extract.
Green	72.31 74.93	0.84 .69	2.71 2.36	7.57 6.97	5.37 4.75	11.20 10.30
Field cured	16.72 17.19	1.71 1.82	5.76 5.56	23.38 23.37	11.84 10.95	40.59 41.11
Artificially cured	3.92 5.94	2.67 3.58	9.13 8.23	29.67 22.51	16.96 18.57	37.65 41.16
Reduced to water-free basis: Green	....	3.03 2.75	9.78 9.41	27.33 27.80	19.39 18.94	40.80 41.04
Field cured	....	2.05 2.19	7.03 6.71	28.07 28.22	14.21 13.22	48.76 49.76
Artificially cured	....	2.77 2.16	9.50 8.75	30.85 23.93	17.65 19.73	39.17 43.75

The early experiments showed that artificial curing was successful in so far as color and feeding value, as determined by chemical examination, were concerned.

Extended inquiry failed to discover any type of kiln on the market, such as is in use for the drying of other products, that could be made available for the haying industry. The pioneer work of designing and erecting a drying plant encountered many difficulties; and, in the absence of data for the solution of the various problems, progress was necessarily slow.

WORK IN THE YEAR 1909.

As originally designed, the machinery of the hay-drying kiln consisted of seven endless conveyors arranged in a building 20 feet high.

(Fig. 1.) The hay to be cured is fed into these conveyors by means of an inclined elevator, the lower end of which is at a convenient height for the haymakers that bring the supply from the field. The top conveyor travels from front to rear a distance of 30 feet and there

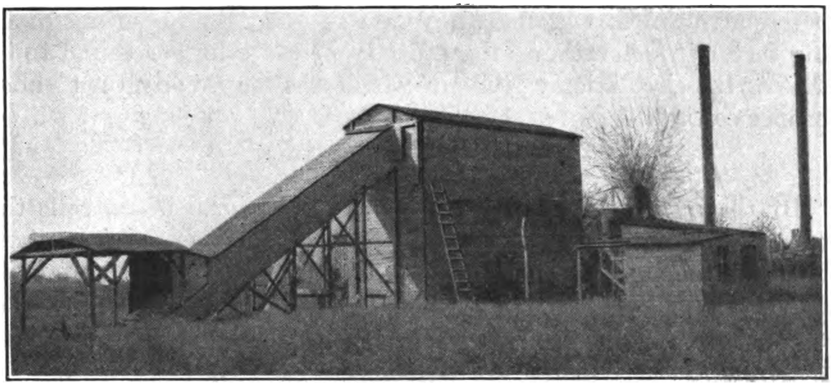

FIG. 1.—Front view of hay-drying plant, showing driveway with shed for protection from rain and inclined feed elevator connecting with building 30 by 12 feet in size and 20 feet high, in which the machinery of the kiln is installed. The smaller building at the right contains the condensing apparatus; back of all are the boilers furnishing power and heat.

drops the hay to the conveyor immediately below, which travels in the opposite direction. The hay passes back and forth in this manner over the seven conveyors, and is finally delivered to a second shorter discharge elevator (fig. 2) which communicates with the storage

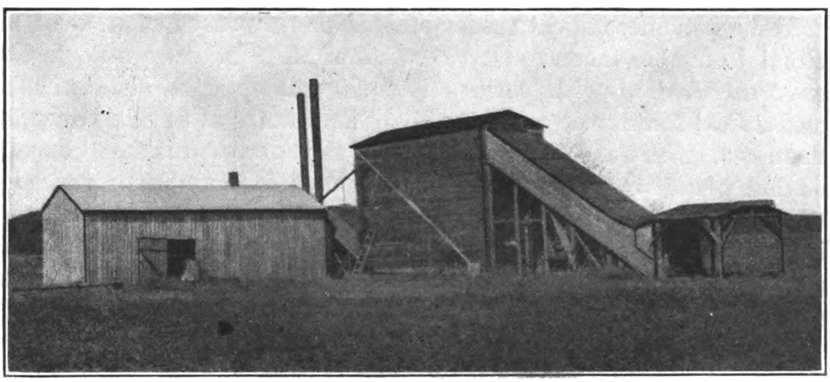

FIG. 2.—Side view of hay-drying plant, showing shorter elevator in the rear for delivery of the cured product to the storage barn shown at the left.

barn. A system of steam coils installed beneath the conveyors provides the means of maintaining the desired degree of heat. The kiln erected in 1909 was provided with a condenser, so that it could be operated in a closed circuit, free from the conditions of the external air. Several test runs were made in the fall of 1909.

WORK IN THE YEAR 1910.

Test runs were made during the season of 1910 on each crop of alfalfa, and the results obtained were of much value. It became evident that the capacity of the plant would have to be increased before artificial curing would become a success. An important limiting factor in determining the capacity of the kiln was found to be that of the circulation of the air, which was too slow and not under proper control.

WORK IN THE YEAR 1911.

By the installation of power fans and additional steam coils the capacity of the plant was greatly increased, and a second important limiting factor was developed, namely, that of the manner of feeding. It was discovered that efficiency depended largely upon the evenness of distribution of the stream of hay in its progress through the apparatus. Whether feeding light or heavy, if hay was placed on the elevator in knots or twists it would not cure. The importance of a mechanical feeder thus became manifest.

A third limiting factor was found to be due to the improper circulation of the air, and a method was devised whereby the heated air was forced straight up through the hay. The necessary mechanical changes were effected, but not in time to be tested during the season of 1911.

WORK IN THE YEAR 1912.

Tests of a mechanical feeder and of the improved method of air circulation were made during the season of 1912. The new devices gave satisfaction with cowpea hay as well as with alfalfa. The mechanical feeder tore apart the wisps and lumps of hay and dropped them evenly on the feed elevator. The capacity of this small experimental plant was found to be 653 pounds of cured hay per hour when working with freshly cut alfalfa. The limiting factors were found to be those of faulty installation, mainly manifest in the temporary character of the building used and in the types of engine and boilers, which were poorly adapted for the purpose.

PROPOSED WORK FOR 1913.

The series of experiments thus far conducted shows a gradual and steady improvement in the system, tending to lower the cost of curing and to increase the capacity of the kiln. Even with the present capacity it is believed that a large plant of the same type would prove profitable where the hay is to be made into meal.

There is every indication that larger circulation, better boiler pressure, and much heavier feeding, combined with somewhat slower run-

ning to permit longer time in the kiln, will give additional increase in capacity.

. It is proposed to further test the present kiln when supplemented by a new 60-horsepower water-tube boiler, two automatic stokers (with fans and other accessories), one 60-horsepower turbine engine, and one alfalfa meal mill and sacker.

CONCLUSIONS.

When the saving made in interest on the investment in land, barns, and tools, by assuring the regular output of crops, regardless of weather, and also the increased nutritive value of the hay produced by artificial means are considered, it would seem that the following conclusions can be safely drawn:

(1) Artificial curing is not adapted to supersede sun or field curing in sections where ideal haying weather conditions prevail, but it will enable the grower, especially in the South, to so cure his entire crop that it will all grade as "Choice" and thus command the highest market price.

(2) Artificial curing may profitably supplement field curing. The hay may be allowed to become partly cured in the field if the weather is favorable. A kiln will cure about twice as much hay containing 40 per cent of moisture as it will when working on unwilted hay.

(3) The cost per ton of curing hay artificially is found to decrease with increasing capacity and efficiency of the plant. The items of cost are (1) interest on investment, (2) repairs of machinery, (3) labor, and (4) fuel. The fuel cost is by far the largest item.

(4) Artificial curing effects an immense saving in the leaves and smaller stems which comprise so large a percentage of the best part of the hay product largely lost by field curing.

(5) The process for the present must be confined to large growers, or to smaller growers operating on a community basis.

(6) The drying plant may be expected to pay for itself in four years under adverse conditions and in a single season under favorable conditions.

O